THE 1.5 GEV OPERATION PARAMETERS AND PERFORMANCE AT SRRC

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Abstract

The storage ring at SRRC is highly promising as an ultra-violet to soft x-ray radiation source for use in basic research and industrial applications. Energy ramping of the storage ring can push the critical photon energy to the edge of hard x-ray. The tune drifting, during the ramping procedure, is expected and should be minimized such that the beam can survive through the ramping process. The betatron frequencies and the ramping function of magnets were carefully monitored in order to avoid the betatron tunes cross fatal resonance line. A successful ramping results and lattice parameters were measured and discussed in this paper. The measured photon flux increased by six to seven folds at the x-ray beam line. Life time reaches 9 hours of 200 mA beam current.

1 INTRODUCTION

The storage ring at SRRC is a source of ultra-violet to soft x-ray radiation for scientific research and industrial applications. The energy ramping from 1.3 GeV to 1.5 GeV increases the photon flux and brightness in the UV and soft x-ray region, and will also push the critical photon energy closer to hard x-ray.

In order to accommodate users with 1.3 GeV and 1.5 GeV operations, SRRC selected the energy ramping project as the highest priority. Since the booster at Taiwan Light Source (TLS) can not inject electrons into the storage ring with energy higher than 1.3 GeV without significant modification of booster and transport line system. The most cost effective way to increase the stored beam energy is to ramp the energy of the storage ring. Energy ramping of stored electrons requires nearly synchronous control of the main storage ring magnets. The seven families of magnets have different properties, making the tracking of the energy ramping difficult.

SRRC hoped to utilize the energy ramping from 1.3 GeV to 1.5 GeV for increasing the photon flux and brightness at x-ray regime. The estimated brightness [1] variation vs. the photon energy for the bending magnet and wiggler device is shown in Fig. 1 with 1.3 and 1.5 GeV beam energy. As a well known phenomena, a shorter wavelength allows for a smaller feature to be observed and written. The potential research area for higher photon energy include general x-ray users, micro-machining, microscopy, lithography and LIGA applications. A successful ramping program also provides a highly effective tool for the machine physicist to examine the machine performance under different electron beam energies, for examples using different energy to estimate the beam lifetime, radiation hazard analysis and energy calibration for the various detectors etc.

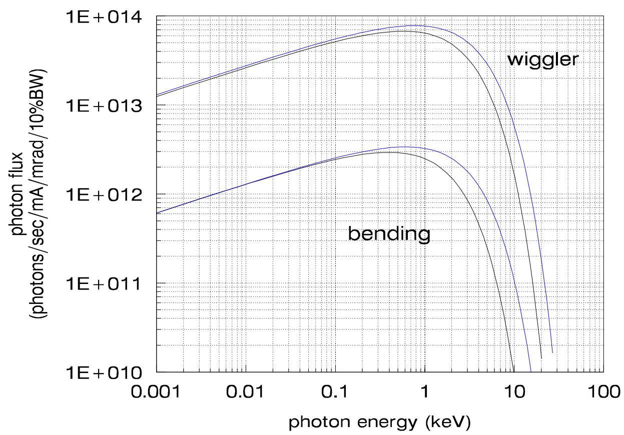

Figure 1. Calculated photon flux vs. photon energy for bending magnet and wiggler at 1.3 GeV and 1.5 GeV beam energy.

The short term approach of increasing the stored beam energy at TLS is using the nominal energy injection from booster, 1.3 GeV, with synchronized or asynchronized ramping of magnets field at the storage ring. However, for a long term planning or in preparing a mini-undulator operation with the necessity of frequent injection, a full energy injection from booster is the long term option to make top-up injection a feasible option.

2 RAMPING AND EXPERIMENT

2.1 Preparing the Storage Ring

Preparation tasks for the energy ramping project include the program coding, temperature measurement of magnets, the stability and capability test of magnet power supplies at high current, and preparation of an interlocking system. The currents of dipole and quadrupole magnets were driven to the maximum capacity of power supplies. Critical temperature of the magnet interlocking system was set at 60℃. If any of the thermal sensors at magnets sense that the temperature exceeds the 60 ℃ limit, the interlocking system interrupts the power supplies to protect the magnet from overheating. This system also protects the vacuum chamber from overheating as well. Several radiation survey meters are also placed around the storage ring to continuously monitor the radiation dosage. Each of the two RF transmitters can deliver 60 kW power to the cavities. According to the power loss estimation, the two transmitters can drive the 1.5 GeV electron beam at beam current as high as 300 mA if beam instability and beam loading problem are not of concern. The radiated power, due to the increase of beam energy, increases by a factor of 68%. Notably, the thermal loading of mirrors along the beam line estimated by the designer is well within the safety margin.

2.2 Beam Behavior during Energy Ramping

Two sets of stripline type beam-position-monitor (BPM), which can pick up a broad-band signal induced by the electron beam, have been installed at the storage ring. Successively analyzing the beam position at fixed BPM can yield information reading of the electron beam's betatron frequency and the bunch distribution of the electron beam. A carefully monitored betatron frequency and ramping function of magnetic setting can prevent the betatron tunes from crossing the resonance line, thereby inducing beam loss during the acceleration. We attempt to maintain the working tune at a constant level. The tune drifting during the ramping procedure should be minimized to allow the beam to survive through the ramping process[2]. During the ramping process, there is no significant beam loss except the scattering loss. A ramping down procedure has also been performed.

The control system of the storage ring power supplies was modified by using AI/AO interface, recently. This will eliminate the handshaking and waiting response time for each GPIB device. Instead of GPIB interface, the AI/AO interface enhances the reading and setting speed which makes the ramping process be completed within 30 seconds. A further shortening of the ramping time is possible, but it is not a critical issue for a storage ring operation.

2.3 Measurement of Beam Parameters

The simulations of beta function, dispersion function, and chromaticities were performed using MAD [5] as major tool. The measurement of the beta function has been carried out which is shown in Fig. 2. The measurement results shows very good agreement with theoretical prediction. A measurement of dispersion function also has been carried out by varying RF frequency and taking the orbit difference to determine. During the normal operation, chromaticities are set to slightly positive in order to suppress instability.

The basic parameters of 1.5 GeV lattice for the electron beam at TLS was listed at Table 1 [3,4,5].

Table 1. The beam parameters for 1.5 GeV operation

Nominal energy	1.5 GeV
Natural beam emittance	2.56×10^{-8} rad m
Radiation loss per turn (dipole)	128.1 keV
Critical photon energy	2.14 keV
photon flux (at critical energy)	2.40×10^{12} (photons/s/mrad, 10% BW, mA)
betatron tune	7.18/4.13
bunch length (RF@800KeV)	9.2 mm

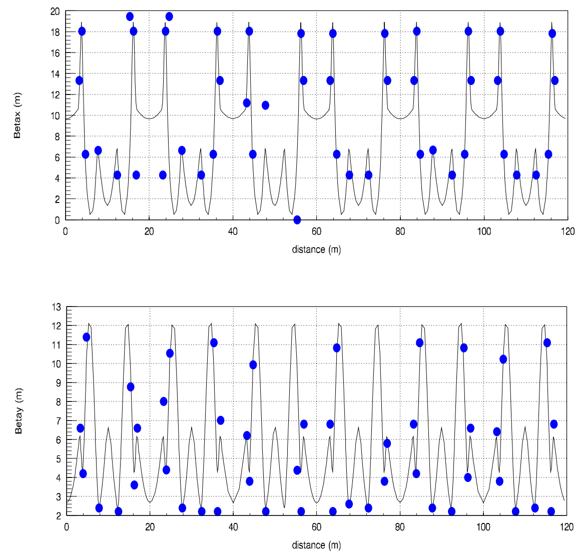

Figure 2 The measured beta function in x-direction and y-direction around the storage ring and compared with theoretical data.

During the users' shift, some long term effects was analyzed by the archived data. From the measurement, the beam lifetime will increase by a factor of 40-50%. The photon stability, which was measured at one of white light beam line using a 50 ℃m pinhole to detect the beam vibration in vertical direction, can be maintained within 0.65%. The close-orbit-distortion in x and y-direction indicated a very good reproducibility.

The variation of photon flux ratio was measured at wiggler and x-ray beam line as shown in Figure 3. Figure 3 shows that the variation of photon flux ratio depends on the photon energy. The higher the photon energy, the larger the photon flux ratio. The betatron tune frequencies converged after three times of 1.3 to

1.5 GeV magnets setting cycling as shown in Figure 4. A normal operation includes the three cycles of magnets setting process to prepare the magnets and eliminate the tune shift. A formal testing of the ramping project to monitor the long term effect which can not be observed during the machine study shifts.

3 SUMMERY

The largest benefit of the energy ramping program for VUV users is the prolong lifetime. 1.5 GeV operation increased the beam lifetime by 40%. The beam lifetime at 1.5 GeV with insertion devices gaps closed is 9 hours compared to 6 hours at 1.3 GeV. The photon stability, which was measured at a focusing white light beam line using a 50 ℃m pinhole to detect the beam vibration in vertical direction, can be maintained within .65%. The closed-orbit-distortion in the transverse directions indicated a very good reproducibility. A ramping loop was also established where the beam can be decelerated from 1.5 GeV to 1.3 GeV and current can be "topped-up" before ramping back to 1.5 GeV.

The improvement in photon flux was measured at wiggler and x-ray beam lines which indicated the flux increased by a factor of two to ten, depending on the photon energy.

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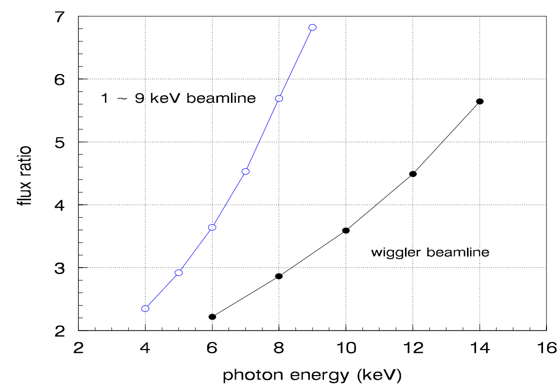

Figure 3. The measurement results of photon flux ratio, the ratio of photoelectron current at 1.5 GeV and 1.3 GeV, vs. photon energy at wiggler beam line and general purpose x-ray beam line.

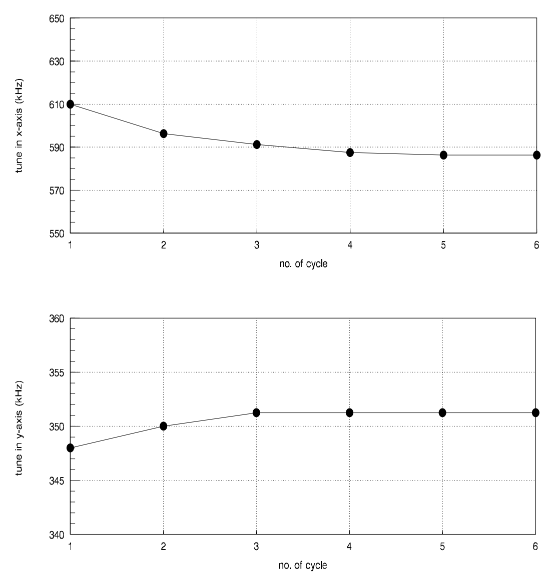

Figure 4. The measured betatron frequency as function of the cycling times, the x-axis is the numbers of cycles between 1.3 GeV and 1.5 GeV lattice setting.